

**Remarks**

This Preliminary Amendment cancels without prejudice original PCT claims 1-15 in the underlying PCT Application No. PCT/DE03/00487, as well as canceling substitute claims 1-14 presented in the Preliminary Examination Report, and adds new claims 16-29. The new claims conform to U.S. Patent and Trademark Office rules and do not add new matter to the application.

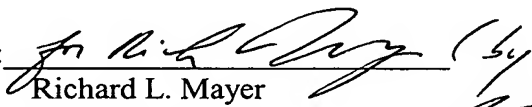
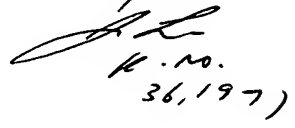
In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(ii) and § 1.125(c), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/00487 includes an International Search Report, dated July 4, 2003. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment. Also enclosed is an English translation of the International Preliminary Examination Report dated June 21, 2004.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,  
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COOLING CIRCUIT FOR AN INTERNAL COMBUSTION ENGINE

~~Background Information~~ Field of the Invention

The present invention relates to a cooling circuit for an internal combustion engine.

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Background Information

A water-cooled internal combustion engine of a motor vehicle is cooled by a coolant, usually water including various additives, which is ~~transported~~ circulated through the engine block and the cylinder head of the internal combustion engine by a main coolant pump. From the cylinder head, the coolant reaches a radiator or, alternatively, a heat exchanger. A cooling circuit for an internal combustion engine, which allows the cooling capacity in different areas of the engine to be adjusted to the actual cooling requirements, is known from ~~DE 199 38 614 A1~~. described in Published German Patent document DE 199 38 614.

A known cooling circuit is first described below in connection with Figure 3, and its disadvantages are explained. Figure 3 shows a schematic representation of a water-cooled internal combustion engine 1. Internal combustion engine 1 includes a cylinder head 3 and an engine block 5, both of which are cooled by a water cooling jacket that is not illustrated. Internal combustion engine 1 is cooled by a first coolant circuit 7, which includes a first flow channel 9, a radiator

11, and a first return channel 13. Installed in first coolant circuit 7 is a thermostat-controlled mixer 15, which, as a function of the temperature of first flow channel 9, controls a bypass 17, which interconnects first flow channel 9 and first return channel 13 while circumventing radiator 11. The thermostat for controlling the mixer 15 is not illustrated in Figure 3, since thermostats of this type are adequately known in the art. A main coolant pump 19, which conducts coolant to engine block 5 of internal combustion engine 1, is installed in first return channel 13.

The section of first flow channel 9 located between mixer 15 and radiator 11, as well as the section of first return channel 13 located between radiator 11 and bypass line 17, are represented by dotted lines in Figure 3 to indicate that mixer 15 has fully opened bypass line 17 and prevents coolant from flowing through radiator 11. Mixer 15 assumes this position when the temperature of flow channel 9 is still low, i.e., when internal combustion engine 1 is still in the cold start phase.

A heat exchanger 23 is supplied with waste heat from cylinder head 3 as needed via a second coolant circuit 21. Second coolant circuit 21 includes a second flow channel 25, a second return channel 27, and a second bypass line 29. The output of heat exchanger 23 may be regulated via a second mixer 31. This output regulation is known in the art and is therefore not described in further detail.

An auxiliary coolant pump 33 is located in second return channel 27. Auxiliary coolant pump 33 is used, according to the known art, to increase the volume flowing through the heating circuit and thus to boost the heating capacity, especially at low engine speeds. A thermostat 35, which

measures the temperature in second flow channel 25, regulates the flow of cooling water through a wiper fluid heater.

5 As mentioned above, internal combustion engine 1 is still in the cold start phase, since first bypass line 17 is fully open and coolant is not yet flowing through radiator 11. The directions of coolant flow in first flow channel 9, first return channel 13, second flow channel 25, second return channel 27, first bypass line 17, and second bypass line 29  
10 are illustrated by arrows in Figure 3. This representation shows that heat is exchanged between engine block 5 and cylinder head 3 within the internal combustion engine, due to the thermosiphon effect. As a result of this internal heat exchange, engine block 5 reaches its operating temperature  
15 only at a slow rate, which is undesirable.

#### Advantages of the Invention Summary of the Invention

20 The present invention provides a cooling circuit for an internal combustion engine that enables the internal combustion engine to be brought to operating temperature as quickly as possible after startup, without the danger of local overheating. In addition, the cooling circuit according to the present invention allows heat to be supplied very quickly to  
25 the heat exchanger, via which heat is supplied to the vehicle interior. To ~~do~~ accomplish this, the return channel from the second coolant circuit, which supplies coolant to the heat exchanger, is connectable to either the return channel or the flow channel of the first coolant circuit, which discharges  
30 waste heat from the internal combustion engine via the radiator. Connecting the second return channel of the second coolant circuit to the first flow channel of the first coolant circuit, while simultaneously taking the second return channel out of service, produces a small cooling circuit that flows

through only the cylinder head of the internal combustion engine, thus preventing the cylinder head from overheating and allowing the engine block of the internal combustion engine to reach its operating temperature as quickly as possible.

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In a first embodiment of the cooling circuit according to the present invention, a main coolant pump is provided in the first coolant circuit, and an auxiliary coolant pump is provided in the second coolant circuit, so that, if necessary,  
10 the discharge of heat from the internal combustion engine is adjustable to the necessary requirements.

| According to further ~~advantageous embodiments~~ example  
embodiment of the present invention, a bypass line for  
15 circumventing the radiator is provided in the first coolant  
| circuit, it being ~~especially~~ advantageous to open or close the  
bypass line in a temperature-controlled manner so that the  
temperature of the internal combustion engine may be  
| maintained at a constant level largely ~~independently~~  
20 independent of the ambient conditions and the internal load of  
the internal combustion engine.

To ensure more comfortable heating of the vehicle interior,  
the auxiliary coolant pump may be regulated or controlled in a  
25 temperature-controlled manner.

| Optimum performance of the cooling circuit ~~is~~ may be achieved  
by operating the cooling circuit according to the following  
procedure:

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- Detection of the temperature of the internal combustion engine.

- Deactivation of the main coolant pump and the auxiliary coolant pump; setting of the distributor to its first position if the temperature of the internal combustion engine is less than a first threshold value.

- Deactivation of the main coolant pump and activation of the auxiliary coolant pump; setting of the distributor to its first position if the temperature of the internal combustion engine is greater than or equal to the first threshold value and less than a second threshold value.

- Activation of the main coolant pump and deactivation of the auxiliary coolant pump; setting of the distributor to its second position if the temperature of the internal combustion engine is greater than or equal to the second threshold value.

Operating the cooling circuit of the present invention according to ~~this~~ the above procedure ensures that the internal combustion engine reaches its operating temperature as quickly as possible, the heat exchanger is supplied with heat as soon as possible and, upon reaching the operating temperature, the internal combustion engine is adequately cooled to avoid overheating in all operating states.

To ~~exclude prevent~~ local overheating during the cold start phase of the internal combustion engine, ~~it is possible according to a further refinement to~~ one may activate the main coolant pump ~~and,~~ deactivate the auxiliary coolant pump and ~~to~~ set the distributor to its second position if the power output ~~by of~~ of the internal combustion engine exceeds a preset limit value. The power output ~~by of~~ of the internal combustion engine may be calculated, for example, on the basis of the product of the rotational speed of the internal combustion engine and the

torque output by the internal combustion engine.

Alternatively, either the torque or the rotational speed alone may be used as the criterion for activating the main coolant pump.

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As a further security measure, the main coolant pump is activated, at the latest, upon reaching a maximum pump deactivation time, which ~~is preferably~~ may be determined as a function of the engine temperature when starting the internal combustion engine.

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| Drawing

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| ~~Further advantages and advantageous embodiments of the present~~  
| ~~invention are derived from the following drawing, the~~  
| ~~description thereof, and the patent claims.~~

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#### Brief Description of the Drawings

Figure 1 shows an exemplary embodiment of a cooling circuit according to the present invention in a first operating state[;]].

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Figure 2 shows an exemplary embodiment of a cooling circuit according to the present invention in a second operating state[;]].

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| Figure 3 shows a prior art cooling circuit ~~according to the~~  
| ~~related art, and.~~

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Figure 4 shows a flow chart of a method for the optimum operation of the cooling circuit according to the present invention.

## ~~Description of the Exemplary Embodiments~~ Detailed Description

~~A cooling circuit according to the related art is first described below on the basis of Figure 3, and its disadvantages are explained. Figure 3 shows a schematic representation of a water-cooled internal combustion engine 1. Internal combustion engine 1 includes a cylinder head 3 and an engine block 5, both of which are cooled by a water cooling jacket that is not illustrated. Internal combustion engine 1 is cooled by a first coolant circuit 7, which includes a first flow channel 9, a radiator 11, and a first return channel 13. Installed in first coolant circuit 7 is a thermostat-controlled mixer 15, which, as a function of the temperature of first flow channel 9, more or less controls a bypass 17, which interconnects first flow channel 9 and first return channel 13 while circumventing radiator 11. The thermostat controlling mixer 15 is not illustrated in Figures 1 through 3, since thermostats of this type are adequately known from the related art. A main coolant pump 19, which conducts coolant to engine block 5 of internal combustion engine 1, is installed in first return channel 13.~~

~~The section of first flow channel 9 located between mixer 15 and radiator 11 as well as the section of first return channel 13 located between radiator 11 and bypass line 17 are represented by dotted lines in Figure 3 to indicate that mixer 15 has fully opened bypass line 17 and prevents coolant from flowing through radiator 11. Mixer 15 assumes this position when the temperature of flow channel 9 is still low, i.e., when internal combustion engine 1 is still in the cold start phase.~~

~~A heat exchanger 23 is supplied with waste heat from cylinder head 3 as needed via a second coolant circuit 21. Second~~



coolant circuit 21 includes a second flow channel 25, a second return channel 27, and a second bypass line 29. The output of heat exchanger 23 may be regulated via a second mixer 31. This output regulation is known from the related art and is therefore not described in further detail.

An auxiliary coolant pump 33 is located in second return channel 27. Auxiliary coolant pump 33 is used, according to the related art, to increase the volume flowing through the heating circuit and thus to boost the heating capacity, especially at low engine speeds. A thermostat 35, which measures the temperature in second flow channel 25, regulates the flow of cooling water through a wiper fluid heater.

As mentioned above, internal combustion engine 1 is still in the cold start phase, since first bypass line 17 is fully open and coolant is not yet flowing through radiator 11. The directions of coolant flow in first flow channel 9, in first return channel 13 as well as in second flow channel 25, second return channel 27 and first bypass line 17 as well as second bypass line 29 are illustrated by arrows in Figure 3. This representation shows that heat is exchanged between engine block 5 and cylinder head 3 within the internal combustion engine, due to the thermosiphon effect. As a result of this internal heat exchange, engine block 5 reaches its operating temperature only at a slow rate, which is undesirable.

Figure 1 shows an exemplary embodiment according to the present invention of a cooling circuit according to the present invention in which this undesirable internal heat exchange does not take place within internal combustion engine 1. The same components are identified by the same reference numbers as in Figure 3, and the remarks made in reference to Figure 3 also apply accordingly to Figure 1. In addition to

the components ~~known from the related art~~ (see shown in Figure 3), the cooling circuit according to the present invention also includes a distributor 39. The ~~second~~ position of distributor 39 shown in Figure 1 establishes a hydraulic connection between second return channel 27 and first flow channel 9 via first bypass line 17. Main coolant pump 19 is deactivated, preventing coolant from flowing through radiator 11. In this position, the coolant flows from second channel 27 to cylinder head 3 via first bypass line 17 and first flow channel 9. The coolant is discharged from cylinder head 3 into second flow channel 25, where it reaches second return channel 27 either via heat exchanger 23 or second bypass line 29. In this configuration of the cooling circuit according to the present invention, coolant does not flow through the engine block, which allows ~~it~~ the engine to ~~heat to~~ reach the operating temperature as quickly as possible.

However, cylinder head 3, which heats up faster than engine block 5, is adequately cooled to avoid impermissibly high operating temperatures in cylinder head 3. If necessary for thermal reasons, it is, ~~of course,~~ possible to also cool the upper area of the cylinders (not illustrated) in the internal combustion engine via cylinder head 3, since this area also belongs to the combustion chamber and therefore is subjected to rapid heating ~~already~~ in the cold start phase. This configuration also ensures that hot coolant flows through heat exchanger 23 as quickly as possible so that the latter may discharge heat as quickly as possible.

If not only main coolant pump 19, but also auxiliary coolant pump 33, is deactivated ~~right~~ at the beginning of a cold start, cylinder head 3 may reach its operating temperature in just a few seconds or minutes, causing the emissions of internal combustion engine 1 to drop very quickly after the

cold start begins. A temperature sensor for measuring the component temperature at the internal combustion engine, in particular e.g., in the area of cylinder head 3, makes it possible to prevent impermissible overheating of the cylinder head. Once cylinder head 3 has reached an adequate temperature, auxiliary coolant pump 33 may be activated, and the state illustrated in Figure 1 occurs.

Figure 2 shows the cooling circuit illustrated in Figure 1, with distributor 39 assuming a first position and connecting second return channel 27 to first return channel 13. In Figure 2, the directions of coolant flow are also indicated by arrows. In this state, main coolant pump 19 is activated so that engine block 5 is also cooled by coolant. Mixer 15 regulates the output of first coolant circuit 7 in the same manner as shown in the related art Fig. 3. The output of heat exchanger 23 is also regulated as known from the related art shown in Fig. 3.

The cooling circuit according to the present invention enables an internal combustion engine to reach its operating temperature as quickly as possible without resulting in disturbing internal heat convection. Different assemblies of internal combustion engine 1 may therefore reach their operating temperatures at different rates. For example, cylinder head 3 usually reaches its operating temperature before engine block 5. As soon as cylinder head 3 has reached an adequate temperature, heat may be discharged via second coolant circuit 21 and used to heat the vehicle interior via heat exchanger 23.

Figure 4 shows a flow chart of a method for operating a cooling circuit according to the present invention. Internal combustion engine is started in a step S1. Immediately after

the internal combustion engine starts, a maximum pump deactivation time  $P_{off, max}$  is set as a function of the engine temperature. This takes place in step S2. A third step S3 checks whether the main coolant pump (abbreviated as HWP) is deactivated for longer than maximum pump deactivation time  $P_{off, max}$ . If this is the case, main coolant pump HWP is activated. A fourth step S4 checks whether the power supplied to the internal combustion engine exceeds a limit value  $P_{limit}$ . If this is the case, the main coolant pump is ~~also~~ activated to avoid overheating the internal combustion engine. Otherwise, a step 5 checks whether temperature  $T_{eng}$  of the internal combustion engine is less than a first threshold value  $T_{s1}$ . If this is the case, main coolant pump HWP as well as the auxiliary coolant pump (abbreviated as ZWP) are deactivated, and distributor 39 is set to its ~~second~~ position shown in Fig. 1. This procedure takes place in a step S6. The query then starts over again at step S3. If temperature  $T_{eng}$  of the internal combustion engine is greater than first threshold value  $T_{s1}$ , main coolant pump HWP remains deactivated, auxiliary coolant pump 33 is activated, and distributor 39 is closed. When distributor 39 is closed, this means that it has assumed its ~~second~~ position shown in Fig. 1.

These operations take place in step S7. If temperature  $T_{eng}$  of the internal combustion engine is less than a second threshold value  $T_{s2}$  but greater than first threshold value  $T_{s1}$ , the sequence starts over again ~~before~~ with third step S3. Otherwise, main coolant pump HWP is activated, auxiliary coolant pump ~~TWP~~ ZWP is deactivated, and distributor 39 is opened, i.e., it assumes its ~~first~~ position shown in Fig. 2 and connects first return channel 13 to second return channel 27.

Operating the cooling circuit of the present invention according to the method described in Figure 4 provides maximum protection of the internal combustion engine against overheating, while simultaneously allowing it to reach its operating temperature as quickly as possible. The vehicle heating system may also be placed into service very quickly.

~~Of course, the output of first coolant circuit 21 and second coolant circuit 21 may be regulated not only according to the operating procedures described in Figures 1 through 3 and the method described in Figure 4, but also in any other manner that is known from the related art.~~

## Abstract

ABSTRACT

A cooling circuit for an internal combustion engine includes a first coolant circuit (7) and a second coolant circuit (21), the cooling circuit being able to be operated by a distributor (39) so that the internal combustion engine (1) reaches its operating temperature as quickly as possible, and a heat exchanger (23) used to heat the vehicle interior is operational as quickly as possible. The return channel from the second coolant circuit is connectable to either the return channel or the flow channel of the first coolant circuit.

~~(Figure 1)~~